

Plant Pigment Puzzle Complete

For about a century, scientists have tried to put together the many pieces of the complicated puzzle of what gives flowers color.

Now, Agricultural Research Service scientists working with color genes have placed the final piece in the puzzle.

“Genetic engineering can be used to create novel flower colors. So foreign flower colors can now be easily introduced into most species,” says flower pigment expert Robert J. Griesbach.

For the last 15 years, this ARS plant geneticist has been working on the plant color puzzle in the U.S. National Arboretum’s Floral and Nursery Plants Research Unit at Beltsville, Maryland.

Says Griesbach, “To create a new palette of flower colors, a thorough understanding of the biochemistry and genetics of flower color was necessary.”

Using petunias, he showed that specific shades of flower color could be explained by the combined inheritance of plant pigments called flavonoids and cell acidity, or pH.

Three different pigments—chlorophyll, flavonoids, and carotenoids—mixed in different proportions, give color to flowers.

“By mixing and matching the three pigments, an endless array of different colors can be created,” Griesbach says. For example, most red phalaenopsis (orchids) are the result of mixing orange carotenoids with magenta flavonoids.

Chlorophyll, responsible for green color, is located in small packets called chloroplasts. The carotenoids that impart yellow through orange colors are found within other small cell packets called chromoplasts.

Unlike those two pigments, flavonoids are located within the

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vacuole, or water-storage area at the center of a plant cell. They make up three-quarters of each flower cell and are responsible for red through blue colors. Flavonoids are divided into two groups—pigmented anthocyanins and colorless copigments.

“While very little is known about the biochemistry of chlorophyll and carotenoids as related to flower

color,” says Griesbach, “we have a lot of information about flavonoid chemistry and flower color. Flavonoid research is 20 years ahead of carotenoid research.

“Once the biochemistry of flower color is known for a specific plant, it will be possible to create an infinite range of custom-colored flowers using genetic engineering,” he says.



Creating a Rainbow of New Flower Colors

“The drawback is the cost of doing the chemical analysis necessary to create novel plants like blue roses.”

Plant flower color is also influenced by the cellular environment—especially the pH of the plant vacuole and the presence of metal ions, says Griesbach.

“In flowers, flavonoids are arranged like a sandwich. Picture the

anthocyanins as the filling and the copigment as the bread. Holding this sandwich together, like mayonnaise, are metal ions that keep the structure from falling apart.

“Cellular pH determines the space between the sandwich—squashing or widening the stacking,” he says. “Changing the distance between the ‘bread’ changes the color.”

For example, changing the pH in petunias by just one-tenth changes their color from blue to red.

Griesbach explains that his color-triggering discovery built on the pioneering biochemical research in the 1960’s by a group of ARS scientists at Beltsville headed by Sam Asen. Their experiments showed that roses and cornflowers both have some of the same anthocyanin. But one is red, and the other is blue.

The earlier researchers demonstrated how subtle changes in cell pH during the day were responsible for the flower’s changing colors—pink as a bud, blue in open bloom, and pink again when the bloom wilted. Their discovery led to the identification of copigment and the role of pH in flower colors.

More recently, the physics of the role of pH in plant color was explained by two Japanese scientists, T. Kondo and T. Goto. They used morningglories to show that cell pH affects color.

Griesbach says that the same principle causes color changes in hydrangeas. “A soil pH of 6.0 will produce pink flowers, while a pH of 5.5 will produce blue ones,” he says. “The soil pH does not influence the pH of the flower cells. But when soil is acidic (around 5 pH), aluminum becomes more soluble and is taken up by the plant. When aluminum binds to the anthocyanin/copigment complex, it changes the hydrangea’s color from pink to blue.

“Light and temperature can also affect flower color. Bright light and cool temperatures during flower development can make blooms more vibrant.”—By **Hank Becker**, ARS.

Robert J. Griesbach is in the USDA-ARS Floral and Nursery Plants Unit, U.S. National Arboretum, Bldg. 010, 10300 Baltimore Ave., Beltsville, MD 20705-2350; phone (301) 504-6574, fax (301) 504-5096. ♦